REVIEW ARTICLE

Review on Biocomposite Application in Waste Water Remediation

Mejeh Kingsley Ikechukwu[1*], Olisa Yemi Philips[2], Okpala Alexander Nwachukwu[2]

[1]Department of Mechanical Engineering, Abia State Polytechnic, Aba. Abia State, Nigeria
[2]Department of Mechanical Engineering, Niger Delta University,
Amassoma, Bayelsa State, Nigeria

ABSTRACT: This research discusses the utilization of natural coagulants and adsorbents as eco-friendly substitutes for chemical coagulants in water treatment. It examines the effectiveness of both plant-based and non-plant-based products in this regard. Additionally, the study explores the advantages, constraints, future possibilities, and economic considerations associated with the use of natural treatment agents.The utilization of bio-composites in wastewater treatment can contribute to sustainable and cost-effective environmental practices, as it reduces the reliance on chemicals. By incorporating bio-composites into these processes, the dependence on chemical substances can be minimized, promoting a more eco-friendly approach. The study presents the use of bio-composite as alternative to chemicals in water treatment. By presenting great benefits such as biodegradability, low index of residual sludge formation, a non-corrosive nature and non-toxicity, the use of this bio-composite would help in sustainable, economic environmental practices, and harnessing them for water and wastewater treatment would help reduce chemical dependency.

KEYWORDS: Bio-materials, Water treatment, *Moringa Olifera*, Remediation, Activated carbon

https://doi.org/10.29294/IJASE.10.1.2023.3304-3323 **©2023 Mahendrapublications.com, All rights reserved**

1. INTRODUCTION

Water contamination is a key issue that affects the entire world. Water pollution has contributed to negative environmental and human health impacts. Water pollution, among other types of pollution, has become a major issue for developing and fast-growing countries, which are particularly vulnerable. Increased pollution and poisoning of aquatic sources not only harms aquatic biota, but it also adds to widespread recreational water shortages [1]. Wastewater is described as water that has had its chemical, biological, or physical qualities altered as a result of certain substances placed into it, rendering it unfit for specific uses such as drinking. Man is mostly reliant on water for his daily activities, and as a result, waste is discharged into the water. Body waste (feces and urine), food scraps, hair shampoo, fat, hair, laundry powder, toilet paper, conditioners, fabric, detergent, household cleansers, chemicals, filth, microorganisms (germs) that can make people sick, and environmental harm are just a hand full of the substances. It is well known that much of the water supplied ends up as wastewater, necessitating its treatment. Wastewater treatment is the technology and method for removing the majority of toxins contained in wastewater in order to maintain optimal environmental public health. Wastewater management thus entails handling wastewater for environmental preservation in order to maintain economic, social, public health, and political stability [2]. Wastewater is also referred to as:

Stormwater Runoff: is water that flows via sewers or drains after a rainfall event from open yards, roadways, and other areas.

Industrial Wastewater: Wastewater from industrial institutions, such as manufacturing units, factories, and so on, is referred to as industrial wastewater.

Domestic wastewater: which can also be called municipal wastewater, is essentially wastewater from commercial buildings (e.g., hotels), Institutions, houses (homes), and hotels (e.g. university).

Greywater : This is another type of wastewater. Sullage is another term for greywater. It's liquid waste from kitchens, laundries, and restrooms that doesn't include any human or animal excreta.

Blackwater: Toilet waste is referred to as

**Corresponding Author: mejekingsley@gmail.com*

Received: 18.06.2023 **Accepted:** 27.07.2023 **Published on**: 25.08.2023

blackwater. In addition to pee and feces, blackwater may contain flush water (excreta). Night soil is a term used to describe a mixture of urine and feces.

Depending on where it comes from, wastewater has varying properties. In wastewater, there are three sorts of contaminants: physical, chemical, and biological.

2 CHARACTERISTICS OF WASTE WATER

Wastewater contains many different substances that can be used to characterize it. The specific substances and amounts or concentrations of each will vary depending on the source. It is difficult to precisely characterize wastewater. Instead, wastewater characterization is usually based on and applied to an average domestic wastewater.

Physical Characteristics: The properties of wastewater, including its color, smell, temperature, and rate of movement, can be used to evaluate its physical attributes.

Turbidity: Typically, sewage appears cloudy and resembles unclean dish water or wastewater from baths, containing various suspended substances such as fecal matter, paper fragments, discarded cigarette ends, matchsticks, greasy substances, remnants of vegetables, fruit peels, soaps, and similar materials. The turbidity increases as sewage becomes stronger. The degree of turbidity can be measured and tested by turbidity rods or by turbid-meters, as is done for testing raw water supplied.

Color: Fresh wastewater typically exhibits a light brownish-gray hue. However, typical wastewater appears gray and displays a cloudy appearance. If wastewater is allowed to become septic due to an increase in travel time within the collection system, its color will undergo a noticeable change. Septic wastewater typically presents a black color.

Odor: The unpleasant smells present in household wastewater are commonly generated by gases resulting from the breakdown of organic matter or the introduction of certain substances into the wastewater. Fresh domestic wastewater has a musty odor. If the wastewater is allowed to go septic, this odor will significantly change to a rotten egg odor associated with the production of hydrogen sulfide (H_2S).

Temperature: Wastewater tends to have a higher temperature than the water supply, primarily because it contains warm water from residential and industrial sources. However, when there are substantial inflows of infiltration or storm water, the temperature of the wastewater can experience significant fluctuations. The temperature exerts an influence on the biological functions of bacteria found in sewage, as well as the solubility of gases within it. Moreover, the viscosity of sewage is influenced by temperature, which, in turn, impacts the sedimentation process during its treatment

Chemical Characteristics: In describing the chemical characteristics of wastewater, the discussion generally includes topics such as organic matter, the measurement of organic matter, inorganic matter, and gases. For the sake of simplicity, chemical characteristics can be described in terms of alkalinity, BOD, chemical oxygen demand (COD), dissolved gases, nitrogen compounds, pH, phosphorus, chloride and solids (organic, inorganic, suspended, and dissolved solids).

Total Solids, Suspended Solids and Settle able Solids:

Most pollutants found in wastewater can be classified as solids. Wastewater treatment is generally designed to remove solids or to convert solids to a form that is more stable or can be removed. Sewage typically contains a very small amount of solids compared to the large volume of water (99.9%). It consists of approximately 0.05 to 0.1 percent (equivalent to 500 to 1000 mg/l) of total solids.

The solids present in sewage can be categorized into four forms: suspended solids, dissolved solids, colloidal solids, and settleable solids. Suspended solids refer to solid particles that remain floating in sewage. Dissolved solids are those that remain dissolved in sewage, similar to how salt dissolves in water. Colloidal solids are finely divided solids that exist either in solution or in suspension. Settleable solids are the portion of solid matter that settles out when sewage is allowed to remain undisturbed for a period of 2 hours.

The proportion of these different types of solids is generally distributed as follows:

Inorganic matter consists of minerals and salts, like: sand, gravel, debris, dissolved salts, chlorides, sulphate etc. Organic matter consists of:

(i) Carbohydrates such as cellulose, cotton, fiber, starch, sugar, etc.
(ii) Fats and oils received from kitchens, laundries, garages, shops, etc.
(iii) Nitrogenous compounds like proteins and their decomposed products, including wastes from animals, urea, fatty acids, hydrocarbons, etc.

Alkalinity: This is a measure of the wastewater's capability to neutralize acids. It is measured in terms of bicarbonate, carbonate, and hydroxide alkalinity. Alkalinity is essential to buffer (hold the neutral pH) of the wastewater during the biological treatment processes.

pH:This is a method of expressing the acid condition of the wastewater. pH is expressed on a scale of 1 to 14. For proper treatment, wastewater pH should normally be in the range of 6.5 to 9.0. Determining the pH value of sewage is crucial because the effectiveness of specific treatment methods relies on having an appropriate pH level. It is worth noting that fresh sewage is typically alkaline, with a pH higher than 7. However, over time, the pH of sewage tends to decrease due to the generation of acids through bacterial activity in anaerobic or nitrification processes. The pH, however, rises upon treatment of sewage.

Chloride Contents: Chlorides are commonly found in municipal sewage and originate from various sources such as kitchen waste, human feces, and urinary discharges. The typical chloride content in domestic sewage is around 120mg/l, while the acceptable chloride content for water supplies is set at 250mg/l. However, industries like ice cream plants and meat salting facilities can introduce significant amounts of chlorides into sewage, resulting in an increase in chloride levels beyond the normal range. Hence, when the chloride content of a given sewage is found to be high, it indicates the presence of industrial wastes or infiltration of sea water, thereby indicating the strength of sewage. The chloride content in wastewater, such as sewage, can be determined by conducting a titration using a standard silver nitrate solution. Potassium chromate is commonly used as an indicator during this process, similar to its use in testing water supplies.

Dissolved gases: These are gases that are dissolved in wastewater. The specific gases and normal concentrations are based upon the composition of the wastewater. Typical domestic wastewater contains oxygen in relatively low concentrations, carbon dioxide, and hydrogen sulfide (if septic conditions exist).

Nitrogen compounds: The type and amount of nitrogen present will vary from the raw wastewater to the treated effluent. Nitrogen follows a cycle of oxidation and reduction. The presence of nitrogen in sewage indicates the presence of organic matter and can manifest in one or more of the following forms: Free ammonia, called ammonia nitrogen; Albuminoidal nitrogen, called Organic nitrogen; Nitrites; and Nitrates.

Phosphorus: This element is essential to biological activity and must be present in at least minimum quantities or secondary treatment processes will not perform. Excessive amounts can cause stream damage and excessive algal growth. Phosphorus will normally be in the range of 6 to 20mg/l. The removal of phosphate compounds from detergents has had a significant impact on the amounts of phosphorus in wastewater.

Presence of Fats, Oils and Greases: Greases, fats and oils are derived in sewage from the discharges of animals and vegetable matter, or from the industries like garages, kitchens of hotels and restaurants, etc. Such matter form scum on the top of the sedimentation tanks and clog the voids of the filtering media. They thus interfere with the normal treatment methods, and hence need proper detection and removal. The amount of fats and greases in a sewage sample is determined by making use of the fact that oils and greases are soluble in ether, and when the ether is evaporated, it leaves behind ether soluble-matter, which represents the quantity of fats and oils. Therefore, to determine their quantity, a sewage sample is initially evaporated. The remaining solids are subsequently combined with ether (hexane). Afterwards, the solution is separated and evaporated, resulting in the fats and greases remaining as a residue that can be conveniently weighed.

Sulphides, Sulphates and Hydrogen Sulphide Gas: The determination of suphides and sulphates in sewage is rarely called far, although their presence reflects aerobic, and/or anaerobic decomposition. The decomposition of

sulfur-containing substances in sewage results in the formation of sulfides and sulfates. This decomposition process also generates hydrogen sulfide gas, which contributes to unpleasant smells and odors. Additionally, the presence of hydrogen sulfide can lead to corrosion in concrete sewer pipes.

In aerobic digestion of sewage, the aerobic and facultative bacteria oxidize the sulphur and its compounds present in sewage to initially form sulphides, which ultimately break down to form sulphate ions (SO_4^{2-}), which is a stable and an unobjectionable end product. The initial decomposition is associated with formation of H_2S gas, which also ultimately gets oxidized to form sulphate ions. In anaerobic digestion of sewage, however, the anaerobic and facultative bacteria reduce the sulphur and its compounds into sulphides, with evolution of H_2S gas along with methane and carbon dioxide, thus causing very obnoxious smells and odours. If, however, the quantity of H_2S in raw sewage is below 1ppm, obnoxious odours are not felt.

Dissolved Oxygen (DO): The measurement of dissolved oxygen (DO) in sewage is highly significant for several reasons: When treated sewage is discharged into a river or stream, it is crucial to maintain a minimum of 4ppm of DO to prevent the death of fish and avoid disturbances in the surrounding area. To ensure compliance with this requirement, DO tests are conducted throughout the sewage treatment process. Testing DO levels in sewage before treatment also provides insights into the sewage's condition. It is widely acknowledged that only newly generated sewage contains a certain amount of dissolved oxygen, which is rapidly consumed through aerobic decomposition. Additionally, the amount of dissolved oxygen in fresh sewage is influenced by temperature. If the temperature of sewage is more, the DO content will be less. The solubility of oxygen in sewage is 95% of that in distilled water. The DO content of sewage is generally determined by the Winkler's method which is an oxidation-reduction process carried out chemically to liberate iodine in amount equivalent to the quantity of dissolved oxygen originally present.

Bio-Chemical Oxygen Demand (BOD): Biochemical oxygen demand (BOD) is a measurement used to assess the amount of oxygen required for the aerobic biodegradation of organic matter in wastewater. It serves as a metric to determine the oxygen demand of microorganisms involved in the biochemical breakdown of biodegradable substances present in the wastewater. The BOD value provides an indication of the level of pollution and the potential impact of the wastewater on the receiving water bodies. The rate of oxygen consumption in wastewater is influenced by various factors, including temperature, pH, the presence of specific microorganisms, and the nature of organic and inorganic substances in the wastewater. BOD has a direct impact on the dissolved oxygen (DO) levels in the wastewater. A higher BOD leads to a faster depletion of oxygen in the water, resulting in a reduced oxygen supply for higher forms of aquatic life.

The consequences of elevated BOD levels mirror those associated with low DO levels: aquatic organisms experience stress, suffocation, and eventual death.

BOD is one of the most important and useful parameters (measured characteristics) indicating the organic strength of a wastewater. BOD measurement permits an estimate of the waste strength in terms of the amount of dissolved oxygen required to break down the wastewater.

Chemical Oxygen Demand (COD): The COD is a metric that quantifies the collective oxygen requirement for converting organic substances into carbon dioxide and water, serving as an indicator of the general organic composition or contamination level present in a specimen. By measuring the COD, we can assess the oxygen demand of a substance or wastewater and understand the extent of organic pollution present. The oxygen required to oxidize the organic matter present in a given wastewater can be theoretically computed, if the organics present in wastewater are known. Thus, if the chemical formulas and the concentrations of the chemical compounds present in water are known to us, we can easily calculate the theoretical oxygen demand of each of these compounds by writing the balanced reaction for the compound with oxygen to produce CO_2, H_2O and oxidized inorganic components. Hence, if the organic compounds and their concentrations are known, the theoretical oxygen demand of the water can be accurately calculated, but it is virtually impossible to know the details of the organic compounds present in any natural raw water or a waste water.

Total Organic Carbon: Another important method of expressing organic matter is in terms

of its carbon content. Carbon is the primary constituent of organic matter, and hence the chemical formula of every organic compound will reflect the extent of carbon present in that compound. Known concentrations of such chemical compounds in a given wastewater will thus enable us to theoretically calculate the carbon present in that wastewater per liter of solution.

Biological Characteristics

The bacterial characteristics of sewage are primarily attributed to the presence of bacteria and various other living microorganisms, including algae, protozoa, etc. The former is more active. Most of the vast number of bacteria present in sewage (of the order of 5 - 50 billion per liter of sewage) is harmless non-pathogenic bacteria. They are useful and helpful in bringing oxidation and decomposition of sewage. A little number of bacteria, however, is disease producing pathogens, and it is they who constitute the real danger to the health of the public.

In case of sewage, the routine bacteriological tests as performed on water supply samples are generally not performed, because of the high concentration of bacteria present in it. But at the times of epidemiological investigations, certain tests may be useful for separating the pathogenic bacteria. The bacteriological counts may also be useful where the treatment processes are likely to be affected adversely by bactericidal industrial wastewaters.

3CONCEPTUAL FRAME WORK ON WASTEWATER MANAGEMENT

Waste Water Treatment is a relatively new activity, not minding the fact that drainage systems were developed well before the eighteenth century. Employees used to collect night soil with buckets along streets, which they brought and emptied into honey wagon tanks. Agricultural lands were sold off in rural communities. In the nineteenth century, flush toilets increased the amount of waste generated on these agricultural regions. Due to transportation issues, communities used drainage and storm sewers to transfer wastewater into water bodies. Many possibilities were tested between the late 1800s and the early 1900s. The procedures that we use today were first tried around 1920. However, until the mid-nineteenth century, its design was empirical. This prompted the development of centralized wastewater systems, which was praised. The cost of wastewater treatment was borne by the communities that discharged into the plant. Today, more effort is being made to create portable water from wastewater.

In recent years, regardless of the size of the receiving stream, a significant amount of treatment has been necessary before discharge permits may be given [3]. This can be accomplished by transitioning from centralized to more sustainable decentralized wastewater treatment, particularly in developing nations like Nigeria. The majority of these countries still developing have inadequate wastewater infrastructure, making conventional approaches difficult to manage. For the reasons stated above, wastewater treatment becomes extremely vital. It is crucial for the following reasons:

Reduction of biodegradable organic substances in the environment: Organic components such as nitrogen, carbon, phosphorus, and sulphur that are present in organic matter are broken down by oxidation into gases that are either retained in solution or released**.**

Reduction of nutrient concentration in the environment: nutrients such as nitrogen and phosphorus from wastewater in the environment enrich or make water bodies eutrophic, allowing algae and other aquatic plants to proliferate.

Elimination of pathogens: Aquatic life suffers due to these plants depleting oxygen in water bodies. Pathogens are bacteria, viruses, and other organisms that cause disease in plants, animals, and humans. These microorganisms, commonly referred to as viruses (e.g., enterovirus, hepatitis A and E virus), bacteria (e.g., vibrocholerae), and fungi (e.g., Candida albicans), are also known as microorganisms due to their minuscule size, rendering them invisible to the naked human eye. Candida albicans) and protozoa (Candida albicans) (e.gentamoebahystolitica, giardia lamblia), Infected humans and animals emit large amounts of these microorganisms in their feces [4].

Water reuse and recycling**:** Water is a finite and scarce resource that is often taken for granted. There has been an increased population since the second part of the

twentieth century, putting pressure on already restricted water resources. The agrarian nature of many locations has also changed due to urbanization. Increased population necessitates the production of more food, and agriculture, as we all know, is by far the largest user of available water, implying that economic growth places new demands on existing water supplies. With ground water resources becoming depleted, the spatial and temporal distribution of water is also a key concern. Because of these factors, reuse and recycling are critical for long-term sustainability.

3.1 Wastewater treatment processes

Rain infiltration of the soil and subsurface results in the groundwater, and the final composition of the water are dependent on both specific geological formations and the residence time of the water [5]. The movement of groundwater depends on the permeability of the water bearing layers. Layers such as clay have a low permeability and tend to inhibit water flow, whereas sand or chalk layers have a high permeability and promote water flow. The classification of groundwater is based on its composition, which includes cations, anions, uncharged species, trace components, and gases like CO_2, H_2S, CH_4, O_2. It also encompasses organic compounds and anthropogenic substances such as pesticides and chlorinated solvents [6]. The initial treatment steps fall under preliminary treatment, followed by subsequent procedures. During the screening process, large floating objects and debris are eliminated from the water. Various types of screens like manual bars, mechanical bars, drum screens, band screens, disc screens, and passive well screens are used for this purpose.

Coagulation is a crucial step that disrupts the charge on particles. Coagulants are added to water to counteract the negative charges of suspended solids, allowing non-settleable solids to settle. The choice of a suitable coagulant depends on various factors such as the type of suspended solids, characteristics of the raw water, facility design, and cost considerations [7].

Flocculation, on the other hand, is a gentle mixing process that facilitates the growth of particles from microscopic micro flocs to visible suspended particles. During this slow mixing, micro flocs come into contact with each other, resulting in collisions and bonding that lead to the formation of larger flocs known as pinflocs. The size of the flocs continues to increase as they undergo further collisions and interactions with inorganic or organic polymers introduced by the coagulant.

Overall, these treatment processes contribute to the removal of impurities, suspended solids, and organic compounds, leading to the enhancement of water quality. It requires around 20 - 45 minutes for this step to take place [8].

Sedimentation: Sedimentation basins are used in conventional plants. Direct-filtration plants skip the sedimentation stage and go directly to filtration. Detention times for sedimentation are in the range of 1 to 4 hours [9].

Filtration: It is the final step in removing suspended matter. It is the process of passing water through a material bed in order to remove impurities. Although the sand filter was often sufficient to reduce the concentration of target parameters below the stated goal, the BAC filter significantly improved the quality of the water. The slow sand filter effectively reduced iron and arsenic concentrations. The DOC was effectively reduced to less than 1 mg/l by the BAC filter. Additionally, the combination of sand and BAC filters resulted in a reduction in color and turbidity [10].

Slow rate gravity filtration involves low filtration rates ranging from 45 to 150 gallons per day per square foot (gpd/sq.ft) or 0.03 to 0.10 gallons per minute per square foot (gpm/sq.ft). The filter media used in this process is a 24 to 30-inch deep bed of silica sand (Logsdon *et al*., 2004).On the other hand, rapid rate gravity filtration differs from slow sand filtration. It employs coarser sand with an effective grain size ranging from 0.4 to 1.2 mm. The filtration rate is much higher, typically between 5 and 15 cubic meters per square meter per hour ($m^3/m^2.h$) or 120-360 cubic meters per square meter per day ($m^3/m^2.day$) [11].

Bioreactors: Bioreactors have been utilized with success for waste-water treatment for over 100 years. Bioreactor processes can be distinguished on the basis of biomass retardment mechanism. Biomass grows on a carrier in attached growth, i.e. biofilm systems or as a suspension in sludge processes [12].

In general, conventional water treatment methods are ineffective in removing salts. According to the European Integrated Pollution Prevention and Control Bureau (EIPPCB), the textile industry releases over 0.2 million tons of

salts into the environment annually, causing disruption to the balance of aquatic ecosystems. Moreover, salts in surface waters can affect also the agricultural activity and salinization of underground fresh water can critically compromise the drinking water resources [13].

Aeration: When oxygen present in the air comes into contact with hydrogen sulfide, it undergoes a reaction to produce sulfate, a dissolved form of sulfur that is odorless. Additionally, when water is aerated, it may result in the formation of some yellow sulfur particles. One method to aerate the water system involves injecting compressed air into it, although the air must be subsequently removed to avoid issues such as knocking or air-blocks within the system. Another approach involves spraying water into a tank that is not pressurized, but in this case, an additional pump is required to re-pressurize the water system. It is common for odors to be present near these aeration systems as hydrogen sulfide gas is released from the water [14].

Methane Removal: Methane (CH_4) is a naturally occurring hydrocarbon that is colorless, odorless and tasteless. Methane, the primary component of natural gas, can create oxygen-depleted atmospheres, flammable conditions, or even explosive environments when present in high concentrations. Since methane is lighter than air, it can often be effectively eliminated from a well by properly venting it into the atmosphere. Proper venting is extremely important and can significantly reduce the amount of methane, as it can trigger an explosion in enclosed/confined spaces containing oxygen, coupled with an ignition source (an open flame or an electrical spark). Methane has the potential to act as an asphyxiant by displacing air in enclosed spaces and substituting oxygen in the circulatory systems of animals. Moreover, when methane is burned, it can generate other harmful gases like carbon monoxide, as noted by [15].

Hydrogen Sulfide Removal: Hydrogen sulfide is formed by sulfur bacteria that may occur naturally in water. These bacteria use the sulfur in decaying plants, rocks, or soil as their food or energy source and as a by-product produce hydrogen sulfide. The sulfur bacteria do not cause disease, but their presence in water can cause a bad taste or odor. Water containing hydrogen sulfide usually does not pose a health risk, but does give water a nuisance "rotten egg" smell and taste. Water sources containing only 1.0 part per million (ppm) of hydrogen sulfide can exhibit corrosive properties, potentially leading to the tarnishing of copper and silverware. In some cases, these water supplies may also release a black substance that can stain laundry and porcelain surfaces [16,10].

Carbon Filters: Very small amounts of hydrogen sulfide can be removed from water with activated carbon filters. The hydrogen sulfide is adsorbed onto the surface of the carbon particles. The activated carbon filter needs to be replaced at regular intervals, which may vary depending on the quantity of hydrogen sulfide present in the water. Moderate to high levels of hydrogen sulfide in water will require very frequent filter replacement [17,18].

Ion Exchange: Ion exchange (IX) is the most broadly working nitrate treatment technology, used at well sites or other points of entry into potable water division systems. Such systems usually treat less than one million gallons of water per day (MGD) to as much as 10 MGD. While nitrate-selective ion exchange (IX) resins have been developed, many of them exhibit greater selectivity towards sulfate rather than nitrate. Consequently, the influence of sulfate on the nitrate exchange capacity needs to be taken into account, as highlighted by [22]. Nevertheless, these technologies are straight forward to design, operate, and monitor. They are cost-effective for smaller applications such as direct treatment of groundwater at well sites, usually feature fully automated regeneration sensors and equipment, and are regenerated using sodium chloride [19]. It is most suitable for waters with total dissolved solids (TDS) concentrations of less than 500 mg/l. Salts and organics in water eventually foul resins, but many systems operate for 5 to 10 years without requiring resin replacement. The primary disadvantage of these systems is the production and costly disposal of concentrated brines, which can contain high concentrations of sodium chloride, nitrate, sulfate, and arsenate. Brines can be disposed of in sewers where adequate dilution is available, but long-term salinity control in some areas may limit this option in the future. Research is now underway to biologically treat ion exchange regeneration brines to remove nitrate and prolong their use prior to disposal [20]. Another major challenge is nitrate removal and the release of

nitrosamines or their precursors, which appear to be by-products or impurities in the resins that are used [21]. Pump-and-treat technologies have been used to clean up the source zone or plume of the contaminants to avoid further contamination of the groundwater by dissolution and dispersion [22].

Metal removal and Softening: Removal of heavy metals is an important process in the water treatment [23]. After the storage tank, the water was softened to reduce hardness for washing and bathing. An ultraviolet (UV) disinfection lamp was installed after the softener on one ground water system to deal with micro biological problems. For drinking and cooking water at each site, a reverse osmosis (RO) membrane, complete with booster pump, was installed as an additional protective barrier at the kitchen sink. The reverse osmosis (RO) unit effectively reduces levels of sulfate, sodium, total dissolved solids, and hardness, which are parameters that the BAC (biologically active carbon) filter does not address, as indicated by Center in 2002 and Kelada in 2000. The RO unit will also remove micro-organisms including bacteria, viruses and parasites, providing it is properly operated and maintained [24].

Pre-chlorination and chlorination: The processes involved before chlorination comes under pre-chlorination step. Upon contact, chlorine rapidly reacts with hydrogen sulfide, resulting in the formation of a yellow particle that is tasteless and odorless. A small amount of chlorine, usually household laundry bleach, can be automatically added to any size water system to remove hydrogen sulfide. The presence of yellow sulfur particles in the water can lead to the formation of a yellow film on clothing and fixtures, as noted by [24]. To address this issue, a sand or aggregate filter can be employed to remove these particles. However, regular backwashing of the filter is essential, typically every few days or weeks, to eliminate the accumulated sulfur particles.

Disinfection: New wells, or old installations after rehabilitation, usually are bacterially contaminated and should be disinfected prior to being placed in service. Chlorine always should be used outdoors or in well-ventilated places because breathing the fumes is dangerous. In heavy concentrations, chlorine also is harmful to skin and clothing. The chlorine must be thoroughly mixed with the water, and then sufficient chlorine contact time must be provided to kill all disease-causing and nuisance organisms [22,25].

Blending: High-nitrate groundwater is largely managed by blending the groundwater with surface water that has lower nitrate concentrations.

Biosorption: Biosorption, considered as a highly beneficial option for eliminating contaminants from water sources, stands out among several biological methods. It involves a physico-chemical process wherein biological material is utilized to extract substances from a solution.
The main advantage includes high efficiency, cost effectiveness and good capacity of removing pollutants from large volumes. There is a major need to generate performance data on real or simulated industrial effluents, since many biotic and abiotic factors can affect biosorption process [26,27].

3.2 Modern Water Treatment Processes

Biological De-nitrification: Microbe-induced nitrate reduction can be accomplished using organic carbon electron donors such as methanol or acetic acid, or inorganic electron donors such as hydrogen or reduced sulfur. However, the dissolved oxygen content of the water must be lowered to about 0.1 mg/l for reduction to occur. Recent advances in hollow-fiber membranes allow autotrophic bacteria to grow on the outside of the membrane in nitrate laden water while hydrogen gas is slowly supplied from within the membranes [28]. Nitrate and oxygen permeate into the biofilms growing on the membranes and are reduced in the anoxic environment within the biofilm; this approach shows significant promise for nitrate reduction. Biological de-nitrification systems do not produce concentrated brine streams, but biofilm growth must be managed [29]. The most significant drawbacks of biological systems are that they require start-up time after prolonged periods of closure (such as in response to seasonal water demand), require more operator support than non-biological systems, and are less mature in the market place than IX systems.

Chemical De-nitrification: Metals such as platinum, palladium, tin and copper can chemically reduce nitrate to other forms, but

they usually require a low pH, often need the addition of hydrogen gas or another strong reductant, and perform best with added heat. As a result, full-scale treatment systems based on these catalysts are not yet used for drinking-water applications. Zerovalent iron (Fe0) has gained the most attention as a nitrate reductant system. Both in-situ groundwater and above-ground treatment systems have been demonstrated at several sites and commercial vendors have recently entered the market place. Oxidation of the iron frees electrons, which are then available for nitrate reduction [28]. Like biological de-nitrification, these systems require low dissolved-oxygen levels to proceed favorably. The precise reactions for Zerovalent iron and other chemical reduction processes are not well known for groundwater matrices but in most cases nitrate reduction in groundwater does not proceed to innocuous gases as it does in distilled water or in biological de-nitrification systems [25]. The bioden process is based on the natural biological de-nitrification, which takes place in soil and ground water. However, in this process the de-nitrification is enhanced under controlled conditions in a fixed bed biofilter. In order to meet drinking water requirements, the de-nitrification process needs an aerobic post-treatment. It consists of the following steps such as substrate dosing, denitrifying biofilter, and aeration, flock-filtration, polishing filter, safety disinfection, backwash system and backwash water recycling. As substrate a carbon and phosphate source are dosed into the raw water. Normally all other nutrients are normally sufficiently present in the raw water [30].

3.3 Treatment Processes for Heavily Polluted Water

Dissolved Air Floatation (DAF):

The DAF range of water treatment plants excel in treating lake and reservoir water containing high levels of colour, algae and turbidity. The treatment plants also provide excellent treatment of cold water with high levels of iron and manganese [30]. This process provides excellent algae removal capabilities and is easy to operate. It can tolerate variations in the quality of the raw water source, allowing for reliable performance. The system also has a quick start-up time and generates minimal plant waste. Furthermore, it offers the advantage of significantly lower construction costs compared to alternative methods [31].

Ozonation: This water treatment process is typically employed to eliminate bacteria and other microorganisms by introducing ozone into the water. Specifically it targets cryptosporidium, bacteria and other naturally-occurring organisms. It also reduces the formation of tri-halo-methanes (THMs), which result from the interaction of chlorine and naturally-occurring organic material in the source water [31].

Granular Activated Carbon (GAC) Adsorption: GAC has an extremely large amount of adsorption surface area, generally around 73 acre/lb (650m^2 /gram) to 112 acre/lb (1000 m^2/gram). GAC (Granular Activated Carbon) is composed of small clusters of carbon atoms arranged in layers. It is manufactured by heating carbon sources such as coal, lignite, wood, nutshells, or peat in the absence of air, resulting in a material with a high carbon content [22].

When it comes to membrane-based processes, such as reverse osmosis (RO) and electro-dialysis (ED), they are generally expensive options for nitrate removal. These methods are primarily utilized for treating water with high total dissolved solids (TDS) rather than specifically targeting nitrate pollution.

These methods are currently used for nitrate removal in smaller communities and military bases [32]. ED-based systems utilize electric current to pass positive ions (cations) or negative ions (anions) through a semi permeable membrane. The current can be adjusted to pass only cations and reject anions, such as nitrate. However, these membrane-based technologies require significant external energy inputs, which lead to high operating costs [33]. Both RO and ED produce concentrated brine streams that require disposal; pretreatment is usually necessary to prevent membrane fouling. Membrane treatment processes such as these can be a viable treatment option for municipalities with existing membrane technologies.

4 APPLICATIONS OF ACTIVATED CARBON IN WATER TREATMENT

Activated carbon is non-graphite, microcrystalline type of carbon. Internal porosity has been developed in this activated carbon, which is characterized by a large specific surface area [34]. Activated carbon is a finely powdered substance, typically black in color that is odorless and tasteless. It is

produced by subjecting materials such as wood or other sources to high temperatures in an oxygen-deprived environment. This process releases trapped gases, resulting in the formation of a highly porous form of carbon. It can be treated or activated to improve its ability to adsorb different substances on the surface of its pores, such as liquids, dissolved substances (adsorbates), or gases, by reheating it or using other chemicals that will break it down into a very fine powder [35]. Activated carbon is cost-effective because it can be reactivated for reuse using the same high-temperature technique that was used to manufacture it. During the regeneration process, organic chemicals that have been adsorbed are thermally removed, and the carbon can then be retrieved for reuse. In commercial separation processes, whether they involve purification or bulk separation, it is essential for the adsorbent material to possess a significant internal volume that can be easily accessed by the components being extracted from the fluid. Such a very porous material, whether inorganic or carbonaceous in origin, naturally occurring or produced, may have molecular sieving capabilities under specific conditions.

Adsorbents need to possess favorable kinetic characteristics, enabling them to rapidly attract adsorbing molecules to the adsorption sites. Additionally, they should exhibit robust mechanical properties, including resistance to attrition and overall strength. In many applications, the adsorbent is typically replaced after usage, making efficient regeneration crucial without compromising its adsorptive and mechanical capabilities. To ensure successful economic competitiveness against alternative separation processes, the production methods of adsorption and the raw materials must eventually be cost-effective [36].In any application, the crucial properties of an adsorbent include selectivity, adsorptive kinetics, capacity, regenerability, cost, and compatibility.

Activated carbon is widely utilized because it provides a large surface area, thanks to its high level of micro porosity. This characteristic enables effective adsorption and facilitates chemical reactions, making it an excellent choice for various applications. The adsorption capacity is high due to the porosity formed during carbonization and the large interior surface area. The development of pore architectures was controlled by the presence of activating agents and carbonization [37]. These materials are distinguished by their exceptionally large specific surface areas, adjustable surfaces with functional groups, and well-developed porosity [38]. To provide surface oxygen functional groups to the carbon, various activation methods, including dry and wet oxidizing agents, are applied. The dry oxidation method has to do with the reaction of oxidizing agents such as phosphoric acid (HP_3O_4), carbon surface and nitric acid (HNO_3), zinc chloride ($ZnCl_2$), hydrogen peroxide H_2O_2, potassium permanganate ($KMnO_4$), potassium hydroxide (KOH), ammonia sulphate (AMS) with hot oxidizing gases like steam and CO_2 at temperatures above 700°C, whereas the wet oxidation [39]. The primary sources of activated carbon are organic materials that have a high carbon content. Examples of such materials include wood, coal, coconut shells, peat, and other similar substances. Granular activated carbon is made by re-compacting, crushing to the right size, grinding, and adding a binder to make it harder. It has applications in wastewater treatment, water purification, discolouration, and the removal of harmful organics, as well as the recovery of organic and inorganic chemicals from gaseous and liquid streams and the ions of heavy metals [9]. It's also used to purify electroplating solution (bright nickel-plating solution), which is a popular method for removing organic contaminants. Ground water remediation, spill cleaning, air purification, gasoline dispersion, volatile organic compound captured from painting, and drinking water filtering are all examples of field and industrial procedures that use activated carbon. Activated carbon is used to treat overdoses and poisonings caused by oral consumption. It reduces poison adsorption by preventing poison from adhering to the gastrointestinal tract. Chromatographic separation of carbohydrates (mono-, di-, trisacchardes) utilizing ethanol solution (5 - 50%) as mobile phase employing activated carbon in a 50 percent w/w combination with celite. The production of activated carbon from industrial waste and agricultural by-products such as walnut shell, cocoa pod husk, periwinkle shell, physic nut waste, peach stone, coconut shells, bamboo stem wastes, and palm kernel shells has recently sparked increased interest [9,37,40,41]. Sugarcane bagasse, rubber seeds, pecan shells, olive stone, apple pulp, palm seed and resins, molasses, and dried sewage sludge, paper mill sludge, old newspapers, and waste tires are among the other materials used

[42,43,44,45]. Commercial activated carbon raw materials are derived from a variety of sources, including refinery residuals, peat, wood, coke, coal, carbon blacks, pitches, and nutshells. These materials are utilized in the production process to create the activated carbon used in various applications. According to literatures, the use of activated carbon in liquid phase adsorption has gained significant popularity as an effective method for removing various pollutants from wastewater. Its efficiency in pollutant removal has made it a preferred choice in this field. In fact, the US Environmental Protection Agency has recognized activated carbon adsorption as one of the most effective environmental control technologies available. Activated carbon is widely employed in industries due to its exceptional adsorption capacity for numerous organic compounds, thanks to its organophilic nature. This adsorbent has the advantage of exhibiting high adsorption capacity due to its high specific surface area, adequate pore size distribution and relatively high mechanical strength [46].

Despite their prolific use, certain problems with the high costs of commercial activated carbons have limited their applications. The high production cost is mainly due to the expensive and non-renewable starting materials such as bituminous coal, lignite and petroleum coke, which is a major economic consideration. As a result, there has been a surge in research interest in developing activated carbons from readily available, renewable, and cost-effective sources, including agricultural and industrial by-products. This trend is driven by the need to find sustainable alternatives and utilize abundant resources to produce activated carbon, reducing reliance on traditional raw materials and promoting a more environmentally friendly approach.

4.1 Adsorption

Adsorption is the phenomenon where molecules of dissolved solids, liquids, or gases are captured and retained on the surface of certain active solids. When a solid surface comes into contact with a solution, there is a tendency for a layer of solute molecules to accumulate on the surface due to imbalances in surface forces. This accumulation occurs through the attractive forces between the solute molecules and the solid surface, resulting in the adsorption process [47]. In liquid phase adsorption, particles like atoms, molecules, or ions present in a liquid move towards a solid surface, where they either bond with the surface or are held there by weak intermolecular forces. The solid material that doesn't dissolve in the liquid is called the adsorbent, while the substances that are attracted and attached to the solid when they are in a liquid state are referred to as solutes, forming the adsorbate upon attachment to the solid. According to Ranade et al., [48] the equilibrium concentration of adsorbate on the adsorbent increases as the concentration of the solute in the liquid increases. However, this relationship remains valid as long as the adsorbent's maximum adsorption capacity is not exceeded. It is crucial to determine the adsorption capacity under consistent temperature conditions concerning the concentration of the substance being adsorbed during the development of adsorption processes. Adsorbents have active sites on their surfaces, which are not entirely occupied by bonding forces between the solid's atoms. These active sites act as attachment points for molecules, thereby contributing to the overall adsorption capacity of the material. Foreign molecules are adsorbed at these active sites.

4.2 Classification of Adsorption

Adsorption can be categorized into two types: physical adsorption, also known as physisorption, and chemical adsorption, also known as chemisorption. Physical adsorption takes place when there are weak inter particle bonds, such as Van Der Waals forces, hydrogen bonds, and dipole-dipole interactions, between the adsorbate and the adsorbent. On the other hand, chemical adsorption occurs when there are strong inter particle bonds formed between the adsorbate and the adsorbent due to the exchange of electrons. Chemical adsorption involves a more significant interaction between the adsorbate and adsorbent, resulting in a stronger binding between the two entities [49]. Physical adsorption results from molecular condensation in the capillaries of the solid which usually occurs in gas phase adsorption. There is a rapid formation of an equilibrium interfacial concentration, followed by the rate of diffusion of the solute molecules within the capillary pores of the carbon particles. The rate varies reciprocally with the square of the particle diameter, increases with increasing concentration of solute and temperature, but decreases with increasing molecular weight of the solute [47]. Physical adsorption is characterized by relatively weak adsorptive

interactions, and it is generally assumed to occur with zero or negligible activation energy. In contrast, chemical adsorption results in the creation of a mono molecular layer of the adsorbate on the surface. This type of adsorption arises from the residual valence forces within the surface molecules, leading to a more potent and specific binding between the adsorbate and the adsorbent [47]. Such interactions often involve a high degree of chemical reaction or molecular configuration specificity, wherein particular functional groups participate in reactions. It occurs due to a chemical interaction between the solid and the solute, with the strength of the chemical bond varying considerably, and traditional identifiable chemical compounds may not necessarily form. The adhesive force in chemisorption is generally stronger than that observed in physisorption, and the heat released during chemisorption is typically significant, comparable to the heat produced during a chemical reaction. Chemisorption takes place when there are robust interparticle bonds between the adsorbate and adsorbent, involving the exchange of electrons, with examples including covalent and ionic bonds [49]. Adsorption is highly regarded as a superior technique compared to other methods due to its various advantages. It is cost-effective, readily accessible, easy to implement, highly efficient, user-friendly, biodegradable, and capable of treating pollutants in a more concentrated form. Additionally, adsorption does not lead to the creation of harmful substances [27].

4.3 Adsorption in wastewater using Activated Carbon

Wastewater Adsorption occurs when molecules of a dissolved chemical spontaneously aggregate on and cling to the surface of an adsorbent material. The adsorbate is the substance on which the adsorption occurs. Adsorption occurs when the attractive forces of carbon, which has a high surface area to volume ratio, make it an excellent medium for adsorption. A gram of commercially available activated carbon equals 1,000 square meters of surface area. The larger the surface area, the greater the chance of contaminating molecules accumulating [50]. Although the absorption characteristics of the material are often boosted by further chemical treatment [51], good enough activation for applications that are practical may arise purely from the areas of high surface.

Adsorption, a time-related phenomena regulated by diffusion, is used to separate products from a process or remove pollutants from a waste stream using activated carbon [51]. The adsorption process can be broken down into three parts. To begin, when a gas or liquid comes into touch with activated carbon particles, the carbon particles' exterior surfaces come into contact with contaminants in the bulk liquid. The adsorbates then diffuse into the pore structure on the inside. The subsequent phase is relatively rapid and entails attracting adsorbates towards the inner surface of the pore walls, where they are held in place by either electrostatic or chemical forces. The nature of the force that binds the adsorbed molecules on the surface determines certain characteristics, including how tightly the molecules are held and whether certain substances will be adsorbed by the solid more strongly than others [52].

The initial two phases of the adsorption process in liquid-phase applications are relatively slow, involving the gradual diffusion of pollutants into the internal pores of the carbon particles. As a result, the rate of adsorption is controlled to some extent by diffusion. There is a precise period required for adsorption to occur in any use of activated carbon, whether extruded, granular, or powdered.

Adsorption in the liquid phase is influenced by a variety of chemical and physical factors. Concentration, pH, temperature, and the species being adsorbed are examples of such factors [53]. The manufacturing of activated carbon consists of two essential procedures: carbonization and activation. Carbonization is the initial step, which aims to remove volatile substances. This process is typically carried out in an inert atmosphere to prevent unwanted reactions. In comparison to the raw coal particle, the coal structure decomposes by breaking the least stable bonds within the structure, which include methylene, oxygen, and sulphur bridges between the aromatic. Mild oxidation with oxidizing gases such as air, CO_2, and steam is used in the final phase of activation to establish a proper pore structure (Moser and Vaughn, 2012). In the final step, several chemical reagents such as KOH, NaOH, H_3 PO_4 and $ZnCl_2$ were utilized. Physical activation and weight loss of the volatile component is the initial stage, followed by chemical activation. As a result of the dehydrogenation process, chemical reagents induce the production of cross-links, resulting in the construction of a

rigid matrix, volatile loss and less prime, and volume shrinkage up consumption. Chemical activation has a number of advantages over physical activation, including shorter treatment times and lower temperature. Moreover, chemically activated, activated carbon possesses a more extensive mesoporosity and a greater surface area compared to physically activated activated carbon [37].

4.4 Mechanism of Adsorption

Solutes can adsorb into the inner surfaces of adsorbents in four stages:

(1) Bulk transport: Adsorbates are carried from the bulk solution to the adsorbent particle's water boundary layer. Movement occurs through diffusion in quiescent water if the adsorbent is suspended, as when powdered activated carbon (PAC) is mixed in a fast mix or flocculator, or by turbulent mixing, as when turbulence flow through a packed bed of granular activated carbon (GAC) or in a sedimentation basin [54].

(2) Film transport: Adsorbents are transported by molecular diffusion through a stationary surrounding layer of water (hydrodynamic boundary layer) that surrounds the adsorbent as water flows by it. The time of this step and, as a result, the distance traveled is determined by the flow rate past the particle; the higher the flow rate, the shorter the distance traveled [54].

(3) Intra-particle transport: Once adsorbates move beyond the hydrodynamic boundary layer, they are conveyed to accessible adsorption sites through the pores of the adsorbent. Intra-particle transport can occur by diffusion over the adsorbent surface (surface diffusion) or by molecular diffusion through the solution in the pores (pore diffusion), with adsorption occurring afterwards [53].

(4) Adsorption of the solute on active sites: Once the absorbates get to an accessible site, an adsorption bond is formed between the adsorbent and the adsorbate. For physical adsorption, this step is quite fast, thus one of the subsequent diffusion phases will control the pace at which molecules are taken from the solution. If a chemical reaction occurs during the adsorption step that modifies the character of the molecules, this chemical reaction may be slower than the diffusion steps, allowing the pace of compound removal to be controlled [55]. Adsorption, which involves the use of activated carbon, has long been considered a standard treatment method for wastewater treatment with high amounts of contaminants. However, because to the high cost of commercial activated carbon, its use has been limited, particularly in underdeveloped nations [56]. Activated carbon is extensively used as an adsorbent in various industries to eliminate and recover organic and inorganic chemicals from liquid and gas streams. Its significant adsorption capacity is attributed to the extensive internal surface area and porosity generated during the carbonization process. The development of pore architectures was controlled by the presence of activating agents and carbonization conditions [56]. Activated carbon preparation is usually divided into two steps. First, there's the physical technique, which involves pyrolysis of the precursor material and gasification of the resulting char in steam or carbon (IV) oxide. A considerable amount of internal carbon mass is removed in order to create the porous structure. Only by burning off a big quantity of char can high porosity carbons be created. Pyrolysis char would be saturated with chemical reagents such as $ZnCl_2$, H_3PO_4, NaOH, and KOH for the chemical procedure [37].

5. APPLICATION OF *MORINGA OLEIFERA* IN WATER TREATMENT

Moringa Oleifera, sometimes called the drumstick tree, is widely recognized as a low-cost, high-quality source of phytochemicals with potential applications in biodiesel production, water purification, functional food preparations, and pharmaceuticals. The presence of functional bioactive compounds, like the organic acids, phenolic acids, minerals, natural sugars, and ph, is attributed to the many biological activities of Moringa Oleifera (MO), which include oxidative DNA damage protection, antiatherosclerotic, antinociceptive, anti-inflammatory, antiproliferation, hepatoprotective, antiperoxidative, cardioprotective, and folk medicinal uses. Moringa Oleifera, specifically its cationic proteins (MOCP) extracted from the seeds, is highly beneficial in water purification due to its coagulant and potent antibacterial properties. Moringa Oleifera methyl esters (MOME), derived from the seed oil, meet the major parameters of biodiesel standards in the US, Europe, and Germany.

Numerous studies have found that the use of Moringa Oleifera seeds for wastewater treatment does not result in any toxic effects [57]. The natural coagulant derived from the seeds is a by-product of the oil extraction process. The residue of Moringa Oleifera seed cake can be directly employed in wastewater

treatment without requiring additional preparation [58]. Extracts from Moringa Oleifera seeds possess properties that inhibit the growth of coliforms and pathogens, reducing the need for disinfection [59].

The use of Moringa Oleifera seed cakes helps remove dirt, solid particles, bacteria, and some fungi from water [60]. However, it is important to note that this method does not guarantee complete elimination of germs. Moringa Oleifera seed cake residue has been found to possess heavy metal adsorption properties, forming complexes when combined with heavy metals [61].

5.1 Botanical Description, Distribution, and Production

Moringaceae is a tree and shrub genus with 13 species found throughout the Indian subcontinent (Moringa concanensis and Moringa Oleifera), Kenya (Moringa rivae and Moringa longituba), south-western and north-eastern Africa (Moringa stenopetala), Madagascar, and Arabia (Moringa hildebrandtii and Moringa drouhardii) [62,63]. Moringa Oleifera is a tropical tree that is dicotyledonous, perennial, and deciduous. The stem is fragile and pale green in color, with drooping branches and bipinnate or, more usually, tripinnate leaves (30-60 cm long) with opposing, elliptical leaflets [64]. Moringa Oleifera, originally from the sub-Himalayan Mountains in northern India, is now widely utilized in tropical and subtropical regions worldwide. Saini [65] examined various aspects of the Moringa Oleifera tree, including its industrial and nutritional applications for humans, as well as propagation methods.

Propagation of Moringa Oleifera is typically done through 0.2-1.0cm long cuttings. It is recommended to space the trees 1.2m apart with 5m between rows for pod production, resulting in approximately 1666 trees per hectare. For leaf production, the cuttings are planted closer together, achieving a density of 1 million trees per hectare. Seed cultivation is not advised due to significant genetic variability resulting from cross-pollination [66].

The Moringa Oleifera tree thrives in direct sunlight and prefers temperatures ranging from 25-35°C. However, it can tolerate higher temperatures up to 48°C, especially at altitudes of 500m, and can grow in slightly acidic to alkaline soil with a pH range of 5.0-9.0. It can withstand frost during winter, varying altitudes, and a range of soil conditions. Moringa Oleifera seeds can be planted immediately after maturity as they do not go dormant and remain viable for up to a year. The tree starts bearing fruit approximately six to eight months after planting, with a lower fruit set in the first one to two years but increasing yields in subsequent years.

The history of Moringa can be traced back to 150 B.C. Evidence from historical records suggests that ancient rulers incorporated Moringa leaves and fruits into their diet to promote mental alertness and maintain healthy skin. Furthermore, it is known that Moringa leaf extract was administered to the Maurian warriors of ancient India during warfare [65]. The consumption of Moringa drink was believed to provide the warriors with additional energy and alleviate the stress and physical discomfort they experienced during warfare. The valiant soldiers were the ones who successfully overcame "Alexander" the Great. Encouraged by the information regarding the Moringa drink, three youthful experts commenced an examination of the nourishing advantages provided by the Moringa tree. As researchers delved deeper into studying Moringa, they were astounded by the abundant nutritional content present in its small leaves and fruits [59]. In addition to being a commonly consumed vegetable in these regions, Moringa is renowned and widely used for its health benefits. Among the general population, it has gained the nickname "the miracle tree" due to its remarkable healing properties for various ailments, including certain chronic diseases.

Numerous investigations have been conducted to isolate bioactive compounds from different parts of the Moringa plant, driven by its diverse applications. Therefore, herbal plants in medicine or known as phytomedicine are still trustworthy and widely applied as one of the alternative way in medicinal field due to its affordable cost [67].

5.2 Water Coagulation Proteins from Moringa Oleifera Seeds

Water coagulation proteins derived from *Moringa Oleifera* seeds have the ability to induce turbidity in water. When these proteins are added to water, they form complexes with suspended particles and impurities, causing them to aggregate and settle. Consequently, the coagulation process temporarily increases the water's turbidity. Nevertheless, the primary objective of employing these proteins is to effectively eliminate the suspended solids and clarify the water, thereby enhancing its quality.

Turbidity is caused by natural organic matter and negatively charged particles present in the water. Due to their surface charge, these particles repel each other, hindering their aggregation and settling. To counter this, an opposite charge is introduced to the water, causing coagulation and destabilization of the suspension by overcoming the repulsive force. Commonly used coagulants for treating turbid water and wastewater include aluminum, FeO_3 salts, and synthetic polymers [68]. However, the use of polymers and synthetic chemicals has several significant drawbacks, such as adverse effects on the environment and human health.

Due to concerns regarding the environment, health, and the cost of synthetic coagulants, natural coagulants have gained popularity [69]. Various natural coagulants, including Moringa Oleifera seeds, Vigna unguiculata, Parkinsonia aculeata, and more recently, Cocos nucifera endosperm, have been utilized [69]. Among these, proteins extracted from Moringa Oleifera seeds have received significant attention in water purification due to their strong antibacterial properties and flocculating capabilities.

The amino acid composition of the proteins isolated from Moringa Oleifera seeds reveals a significant presence of glutamine, arginine, and proline, totaling 60 residues [58]. One of these proteins, Moringa Oleifera cationic protein (MOCP or Flo), is a cationic protein that inhibits bacterial growth and aids in the settling of negatively charged particles in a solution. The amino acid sequence of MOCP closely resembles the 2S albumin found in seed storage proteins such as napins and mabinlins, which are abundant in plant seeds and serve as important nitrogen and carbon sources as well as defense mechanisms in plants [70].

In addition to MOCP, Moringa seeds also contain a 30 kDa thermally resistant coagulant lectin (cMoL), which remains stable at high temperatures (up to 100°C) and exhibits effective coagulation properties within pH ranges of 4.0 to 9.0 when dissolved in water [71].

Based on research, the primary structure of this protein has a molecular mass of 11.928 kDa. Our findings indicate that cMoL consists of three sub units, each weighing 11.928 kDa, and forms a trimer [72]. The positively charged nature of cMoL is attributed to its high content of glutamine (alanine), proline, histidines, and arginines. At pH 7.0, the secondary structure of cMoL is estimated to be 46% alpha helix, 12% beta-sheets, 17% beta-turns, and 25% unordered structures in the a/b tertiary structure class. Recently, Moringa seeds have been reported to contain a chitin-binding protein isoform (Mo-CBP3), which is a 2S albumin protein exhibiting flocculating, antibacterial, and potent antifungal activity.

While the coagulation efficiency of MOCP remains consistent at room temperature, it decreases with longer storage times. Interestingly, the coagulation efficiency of MOCP improves as the initial turbidity of the water increases [73].

The antibacterial effects of MOCP are related to the compound's major structural forms. MOCP is a cationic protein with a net positive charge that assists it in interacting with anionic lipid membranes found in bacteria. MOCP also possesses an amphiphilic helix loop-helix motif that helps bacteria integrate their membranes. MOCPs are specifically targeted, and due to their functional properties, various microorganisms, particularly water borne diseases, are eliminated. The most prevalent mechanism of MOCP antibacterial action has been found as membrane fusion [74]. In solvent defatted seed extracts, improved water coagulants have recently showed efficacy. When compared to poly aluminium chloride (PAC) coagulant, solvent-defatted seed extracts had a coagulant efficiency of 88 percent, while seed extract without defatting had a coagulant efficiency of less than 30 percent.

Moreover, in comparison to hexane or acetone defatted extracts, the use of Soxhlet extraction with ethanol for oil extraction has shown to result in a defatted extract that requires 5-33 times less coagulant protein dosage. The authors suggest defatting the extract with ethanol prior to creating the final extract in order to achieve maximum coagulant effectiveness while reducing the protein content.

5.3 Importance and Uses of *Moringa Oleifera*

Moringa is indeed considered one of the most valuable tropical trees due to its numerous practical applications [59,60]. It is relatively simple to propagate through both sexual (seeds) and asexual (cuttings) means, making its production and management convenient. Additionally, Moringa has the advantage of being able to thrive with minimal requirements for soil nutrients and water once it is established, further adding to its ease of

cultivation. Introduction of this plant into a farm which has a bio diverse environment can be beneficial for both the owner of the farm and the surrounding eco-system.

- Use of eco-friendly Moringa Oleifera as a natural coagulant for the process of coagulation to treat wastewater.
- They are respectful of the environment since they are composed of natural and sustainable compounds throughout their life cycle.
- The cost of natural coagulants will be less compared to chemical coagulants.
- The natural coagulant prevents the wear of the establishment and the machinery, achieving lower maintenance costs.
- Moringa Oleifera is a safe and non-toxic plant that has a low concentration of stifling properties. Its seeds contain edible oil and water-soluble substances, ensuring that it does not leave behind any harmful residues that could harm the environment. Moringa Oleifera leaves are renowned for their high nutritional value. The young leaves are edible and are commonly cooked and consumed similarly to spinach, added to soups, or used in salads. The leaves can be consumed raw, cooked, or dried by spreading them over a screen for several days, then ground into a fine powder that can be used as a nutrient supplement in various foods [58]. This powdered form can be added to foods such as porridge, cereals, and beverages to enhance their nutritional content [67].
- Boiling the Moringa leaves has been found to significantly increase the bioavailability of iron, with three times more iron being bio available compared to consuming the leaves raw. Similar results were observed with powdered Moringa leaves.
- Furthermore, the protein quality of Moringa leaves is highly comparable to that of milk and eggs, indicating its potential as a valuable protein source.

Furthermore, activated carbon derived from Moringa Oleifera has demonstrated an impressive capacity to remove anionic surfactants from wastewater. It exhibits high efficiency, making it a promising agent for water treatment purposes. As water pollution increases due to agricultural and industrial activities, various water treatment methods have been developed. However, many of these methods require significant financial investments.

Aluminum sulfate is used as unadventurous chemical coagulant. But as an alternative natural coagulant, Moringa Oleifera seeds can be used properly. The increasing demand for wastewater treatment has led to a growing need for effective and affordable solutions, especially considering the limited availability of resources due to population pressure. Moringa Oleifera proves to be an economical option for water reuse. Adsorption studies focus on exploring the efficacy and cost-effectiveness of Moringa Oleifera in reducing pollutants in environmental pollution.

Different parts of Moringa Oleifera, including the stem, bark, and roots, have been found to possess antimicrobial activities [67]. The leaves of Moringa Oleifera exhibit antimicrobial and antioxidant properties attributed to phytochemical compounds such as saponins, flavonoids, tannins, and other phenolic compounds. The presence of the compound pterygospermin further enhances the potential antibacterial and fungicidal effects. Additionally, the polypeptides present in Moringa Oleifera adsorbents demonstrate bactericidal properties against various pathogenic bacteria [59].

The seeds of Moringa Oleifera possess cyano-bactericidal activity, meaning they can effectively inhibit the growth of cyano-bacteria. Additionally, the ethyl acetate extract derived from the roots of Moringa Oleifera has shown sensitivity towards bacteria such as Staphylococcus aureus and Proteus mirabilis, indicating its potential antibacterial properties against these strains.

6 CONCLUSIONS

This work presents a review of water treatment management using Activated carbon and Moringa Oleifera. Researchers have also proven the efficacy of activated carbon as one of the best adsorbents for heavy metal uptake from wastewater, among other adsorbents. It is not only thought to be highly successful, but also simple to use and affordable. In addition, when *Moringa oleifera* is compared with conventional chemical coagulants, it has the following advantages such as cost effectiveness, availability, biodegradable sludge, eco-friendly, low sludge volume, it does not produce harmful by-products and it is easily handled as it is not corrosive. These comparative advantages presented them as better bio-based composite

as an adsorbent-coagulator to limit the spread of contaminants within water source.

REFERENCES

[1] Rai, R., Tripathi, P., Vajpayee, V., Jha, M. 2002.Bioaccumulation of Toxic Metals (Cr, Cd, Pb 6and Cu) by seeds of Euryale FeroxSalisb (Makhana).Chemosphere, 46, 267–272.

[2] George Tchobanoglous. , Frank Burton QC. , Metcalf and Eddy Inc, 1991. Wastewater Engineering: Treatment Disposal and Reuse, Third Edition. New York: McGraw-Hill.

[3] Adu-Ahyiah, M., Anku, R..E.2020. Small Scale Wastewater Treatment in Ghana (a Scenerio), Water and Environmental Engineering, Department of Chemical Engineering,Lund University. https://artemisthai.com/wp-content/uploads/2020/05/Appendix-2.-Using-Bio-Plant-in-Small-Scale-Wastewater-Treatment.pdf

[4] Awuah, E., Amankwaa-Kuffuor, R. 2002. Characterisation of Wastewater, its Sources and its Environmental Effects" I-Learning Seminar on Urban Wastewater Management Applied Clay Science 42 137–145.

[5] Kainthola J., Kalamdhad A. S., Goud V. V.,2018, Optimization of methane production during anaerobic co- digestion of rice straw and hydrilla verticillata using response surface methodology, Fuel, 235, 92–99.

[6] Atar, N., Olgun, A., Wang, S. 2012. Adsorption of Cadmium (II) and Zinc (II) on Boron Enrichment Process Waste in Aqueous Solutions: Batch and Fixed-Bed System Studies. Chemical Engineering Journal, 192,1–7.

[7] Gökçek, Ö.B. Özdemir,S. 2020. Optimization of the Coagulation–Flocculation Process for Slaughterhouse Wastewater Using Response Surface Methodology, Clean – Soil, Air, Water.

[8] Barakat, M. A. 2011. New trends in removing heavy metals from industrial wastewater. Arabian Journal of Chemistry, 4(4), 361-377.

[9] Rahmani, K., Mahvi, A.H., Vaezi, F., Mesdaghinia, A.R., Nabizade, R., Nazmara, S. 2009. Bio Removal of Lead by Use of Waste Activated Sludge. International Journal of Environmental Research, 3, 471-476.

[10] Manahan, S. E. 2004. Environmental chemistry. CRC press.

[11] Elberling B., Grundvandskemi. 2002.Groundwater chemistry in: Vandforsyning water supply, 2nd edition, Ingeniorenboger, Copenhagen, Denmark, pp. 83-102

[12] Langwaldt, J. H., Puhakka, J. A. 2000. On-site biological remediation of contaminated groundwater: a review. Environmental pollution, 107(2), 187-197.

[13] Tigini, V., Prigione, V., Giansanti, P., Mangiavillano, A., Pannocchia, A., Varese, G. C. 2010. Fungal biosorption, an innovative treatment for the decolourisation and detoxification of textile effluents. Water, 2(3), 550-565.

[14] Binnie, C., Kimber, M., Smethurst, G. 2002. Basic water treatment. Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge. 1-291

[15] Eltschlager, K. K., Schuss, W., Kovalchuk, T. E. 2001. Carbon Monoxide Poisoning at a Surface Coal Mine- A Case Study. Proceedings of the 27 Annual Conferences on Explosives and Blasting Technique, January 28-31. Cleveland, OH: International Society of Explosives Engineers.

[16] Busenberg, E., Plummer, L.N. 2000. Dating young ground water with sulfur hexafluoride—Natural and anthropogenic sources of sulfur hexafluoride: Water Resources Research, v. 36, p. 3011–3030.

[17] Bansal, R. C., Goyal, M. 2010. Activated carbon adsorption. CRC press.

[18] Khan, F. I., Kr Ghoshal, A. 2000. Removal of volatile organic compounds from polluted air, Journal of loss prevention in the process industries, 13(6), 527-545.

[19] Chen, J. P., Yang, L., Ng, W. J., Wang, L. K., Thong, S. L. 2006. Ion exchange. In Advanced Physicochemical Treatment Processes, pp. 261-292). Humana Press.

[20] Fakhru'l-Razi, A., Pendashteh, A., Abdullah, L. C., Biak, D. R. A., Madaeni, S. S., Abidin, Z. Z. 2009. Review of technologies for oil and gas produced water treatment. Journal of Hazardous Materials, 170(2), 530-551.

[21] Doudrick, K., Monzón, O., Mangonon, A., Hristovski, K., Westerhoff, P. 2011. Nitrate

Reduction in Water Using Commercial Titanium Dioxide Photocatalysts (P25, P90, and Hombikat UV100). Journal of Environmental Engineering, 138(8), 852-861.

[22] Cheremisinoff, N. P., Rosenfeld, P. E. 2009. Handbook of Pollution Prevention and Cleaner Production Vol. 2: Best Practices in the Wood and Paper Industries: Best Practices in the Wood and Paper Industries (Vol. 2). William Andrew.

[23] Nagendra S. 2017. Response surface methodology: advantages and challenges. *www.brad.ac.uk/staff/vtoropov/DO/vol1/Forum_i1_100-104.pdf*

[24] Cobb, A. B.2013. The Basics of Nonmetals. The Rosen Publishing Group.

[25] Amy, G., Bull, R., Craun, G. F., Pegram, R. A., Siddiqui, M., World Health Organization. (2000). Disinfectants and disinfectant by-products.

[26] Barakat, M. A. 2011) New trends in removing heavy metals from industrial wastewater. Arabian Journal of Chemistry, 4(4), 361-377.

[27] Crini, G., Badot, P. M. (Eds.). 2010. Sorption processes and pollution: Conventional and non-conventional sorbents for pollutant removal from wastemasters. Presses Univ. Franche-Comté.

[28] Westerhoff, P., Waldron, B., & Anderson, J. 2009. Kyle Wesley Doudrick. Southwest Hydrology, 8(4), 31.

[29] Zhou, H. 2013. Tertiary Nitrification Using Membrane Aerated Biofilm Reactors: Process Optimization, Characterization and Model Development (Doctoral dissertation). The University of Guelph, Guelph, Ontario, Canada, Zebo Long, August, 2013

[30] Wang, J.-P.; Chen,Y.-Z.; Wang, Y.; Yuan, S.-J., Yu, H.Q.2011.Optimization of the coagulation-flocculation process for pulp mill wastewater treatment using a combination of uniform design and response surface methodology, Water Research, 45, 5633–5640

[31] Logsdonl, G. S., Freeman, S. D., Hulsey, R. A., Veerapaneni, S. 2004. Cryptosporldlum and GilI, Contamination and Removal. Advances in water and wastewater treatment, 487.

[32] Kumar, D. M., Shah, T. 2006. Groundwater pollution and contamination in India: the emerging challenge. IWMI-TATA Water Policy Program Draft Paper,1, 14.

[33] Ganzi, G. C., Jha, A. D., Wilkins, F. C. 2010. U.S. Patent No. 7,744,760. Washington, DC: U.S. Patent and Trademark Office.

[34] Gummas, R..H.. Okpeke, I. 2015. Production of Activated Carbon and Characterization from Snail Shell Waste (Helix Pomatia). Advences in Chemical Engineering and Science, (5):51–61

[35] Tenenbaum, D.J. 2008. Food vs. Fuel: Diversion of Crops Could Cause more Hunger. Environ Health Perspect 116:A254–A257

[36] Thomas, W. J. Crittenden, B. D. 1998. Adsorption Technology and Design. Butter Worth Heinemann: Oxford, UK.

[37] Sricharoenchaikal, V., Pechyen, C., Ahl-ong, D., Atong, D. 2007 Preparation and Characterization of Activated Carbon from the Pyrolysis of Physic Nut (*Jatropha curcas* L.) waste energy. Fuels, **22**, 31-37.

[38] Rezzaee, A., Godini, H., Khavanin, A. 2008 Application of Impregnated Almond Shell Activated Carbon by Zine and Zine Sulfate for Nitrate Removal from Water. Iranian Journal of Environmental Health Science & Engineering, **5**, 125-130.

[39] Jabit, N.B. 2007. The Production and Characterization of Activated Carbon Using Local Agricultural Waste through Chemical Activation Process. http://eprints.usm.my/9576/1/THE_PRODUCTION_AND_CHARACTERIZATION_OF_ACTIVATED_CARBON_USING_LOCAL_AGRICULTURAL_WASTE_THROUGH_CHEMICAL_ACTIVATION_PROCESS.pdf

[40] Razada, R., Otoro, M., Moran, A., Garcia, A.L. 2005. Activated Carbon from Sewage Sludge and Discarded Tyres: Production and Optimization. Journal of Harzadous Materials, 124, 181-191.

[41] Atuyor, E.O. & Badmus, M.A. (2008) COD Removal from Industrial Waste Water Using Activated Carbon Prepared from Animal Horns. African Journal of Biotechnology, **7**, 3887-3891.

[42] Kenneth, C.L., Nasrin, R.K., Marta, C., Giselle, S.,Thiyagarajan, P. 2002. Micro Structural Analysis of Activated Carbons Prepared from Paper Mill Sludge by SANS and BET. Chemical Materials, **14**, 327-333.

[43] Suzuti, M., Matsuzaka, A., Yamada, S., Shimono, M., Abiko, Y., Lnoue, T. 2006. Morphology of Malassez's Epithelial Rest-Like Cells in the Cementum: Transmission

Electron Microscopy, Immuno histochemical, and TdT-Mediated dUTP-Biotin Nick End Labeling Studies. Journal of Periodontal Research, **41**, 280-287.

[44] Ademituyi, F.T., Gumus, R.H., Adejini, S.M., Jasem, O.T. 2009. Effect of Process Conditions on the Characterization of Activated Carbon from Waste Nigerian Bamboo. Journal of theNigerian Society of Chemical Engineers, **24**, 83-94.

[45] Puziy, A.M., Poddubnaya, O.T., Matinez-Atonso, A., Suaraz-Gareia, F., Tascon, J.M. 2002. Characterization of Synthetic Carbon Activated with Phosphoric Acid. Applied Surface Science, 200, 196-202.

[46] Olaniyi, I.; Raphel, O.; Nwadiogbu, J.O.2012. Effect of Industrial Effluent on the Surrounding Environment. Arch.Appl. Sci. Res. 4, 406–413.

[47] Olaoye, R.A.; Oladeji, O.S. 2015.Preliminary Assessment of Effects of Paint Industry Effluents on Local Groundwater Regime in Ibadan, Nigeria. Int. J. Eng. Res. 4, 518–522.

[48] Ranade, V.V.; Bhandari, V.M. Chapter 1 Chemical Engineering and Process Development Division. In Industrial Wastewater Treatment, Recycling, and Reuse: An Overview; CSIR-National Chemical Laboratory: Pune, India, 2014; pp. 1–80.

[49] Raj, K. V., Muneesh, S. 2020. Use of Distinct Parts of Moringa Oleifera in Domestic Wastewater Treatment (An Analogous Study); 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO) Amity University, Noida, India. June 4-5.

[50] Adedapo, A., Falayi, O., Oyagbemi, A. 2014. The anti-oxidant, anti-inflammatory and antinociceptive activities of the methanol leaf extract of *Moringa Oleifera* in some laboratory animals (657.19). FASEB J 28(Suppl 1):657.19

[51] Azad, A.K., Rasul, M. Khan, M.M. 2015. Prospect of *Moringa* Seed Oil as a Sustainable Biodiesel Fuel in Australia: a Review. Procedia Eng 105:601–606. Biotech (2016) 6:203 Page 11 of 14 203 123

[52] Nurul'Ain, B. J. 2007. The Production and Characterization of Activated Carbon Using Local Agricultural Waste through Chemical Activation Process. Master Thesis, Zonguldak Karaelmas University.

[53] Metcalf & Eddy. 2003. "Wastewater Engineering: Treatment and Reuse," Fourth Edition.: McGraw-Hill, New York.

[54] Arora, D . S., Onsare, J . G. 2014. In Vitro Antimicrobial Evaluation and Phytoconstituents of Moringa Oleifera Pod Husks. Ind Crops Prod 52:125–135.

[55] Fakurazi, S., Sharifudin, S.A., Arulselvan, P. 2012. Moringa Oleifera Hydroethanolic Extracts Effectively Alleviate Acetaminophen Induced Hepatotoxicity in Experimental Rats through their Antioxidant Nature. Molecules 17:8334–8350

[56] Akanni, O.E., Adedeji, A.L., Oloke, K.J. 2014. Up Regulation of TNF-A by Ethanol Extract of *Moringa Oleifera* Leaves in Benzene-Induced Leukemic Wister Rat: a Possible Mechanism of Anticancer Property. Cancer Res 74(Suppl 19):3792–3792

[57] Iryani, A., Ilmi, M.M. Hartanto, D. 2017. Adsorption Study of Congo Red Dye with ZSM-5 Directly Synthesized from Bangka Kaolin without Organic Template. Malaysian Journal of Fundamental and Applied Sciences, *13*(4), pp. 832-839

[58] Rahman, M. A., Asadullah, M., Haque, M. M., Motin, M. A., Sultan, M. B., Azad, M. A. 2006. Preparation and Charaterization of Activated Charcoal as an Adsorbent. J. Surface Sci. Technol., **22**: 133-140.

[59] Usharani, K., Umarani, K., Ayyasamy, P.M., Shanthi, K., Lakshmanaperumalsamy, P.2010. Physico-chemical and bacteriological characteristics of Noyyal River and ground water quality of Perur, India. J. Appl. Sci. Environ.Manag. 14, 29–35.

[60] Govardhan, R.S., Negi, P.S., Radha, C. 2013. Phenolic Composition, Antioxidant and Antimicrobial Activities of Free and Bound Phenolic Extracts of Moringa Oleifera Seed Flour. J Funct Foods 5:1883–1891.

[61] Zaku, S.G., Emmanuel, S., Tukur, A.A.,Kabir, A. 2015. Moringa Oleifera: an Underutilized Tree in Nigeria with Amazing Versatility: A Review. Afr J Food Sci 9:456–461

[62] Oyeyinka, A.T., Oyeyinka, S.A. 2018. Moringa Oleifera as a Food Fortificant: Recent Trends and Prospects. Journal ofthe Saudi Society of Agric Sci. (17)2, Pages 127-136

[63] Tir, M. Mostefa, N.M. 2008. Optimization of oil removal from oily wastewater by electrocoagulation using response surface method, Journal of Hazardous Materials. 158,107–115.

[64] Padayachee, B.,Baijnath, H. 2012. An Overview of the Medicinal Importance of Moringaceae. J Med Plants Res 6:5831–5839

[65] Saini, R.K 2015. Studies on Enhancement of Carotenoids Folic Acid Iron and their Bioavailability in Moringa Oleifera and in Vitro Propagation. PhD Thesis, University of Mysore, Mysore

[66] Pandey, A., Pradheep, K., Gupta, R. 2011. Drumstick Tree (Moringa oleifera Lam.): a Multipurpose Potential Species in India. Genet Resour Crop Evol 58:453–460

[67] Leone, A., Spada, A., Battezzati, A. 2011. Cultivation, Genetic, Ethnopharmacology, Phytochemistry and Pharmacology of Moringa Oleifera Leaves: An Overview. Int J Mol Sci 16:12791–12835.

[68] Saini, R.K., Saad, K.R., Ravishankar, G.A. 2013. Genetic Diversity of Commercially Grown Moringa Oleifera Lam. Cultivars from India by RAPD, ISSR and cytochrome P450-based markers. Plant Syst Evol 299:1205–1213

[69] Trinh, T.K., Kang, L.S., 2011. Response surface methodological approach to optimize the coagulation–flocculation process in drinking water Treatment. Chemical Engineering Research and Design 8 9, 1126–1135

[70] Kansal, S.K. Kumari, A. 2014. Potential of *Moringa Oleifera* for the Treatment of Water and Wastewater. Chem Rev 114:4993–5010.

[71] Choy, S.Y., Prasad, K.M., Wu, T.Y. 2014. Utilization of Plant Based Natural Coagulants as Future Alternatives Towards Sustainable Water Clarification. J Environ Sci 26:2178–2189.

[72] Suarez, M., Entenza, J.M. Doerries, C. 2003. Expression of a Plant Derived Peptide Harboring Water-Cleaning and Antimicrobial Activities. Biotechnol Bioeng 81:13–20

[73] Santos, A.F., Luz, L.A., Argolo, A.C. 2009. Isolation of a Seed Coagulant Moringa Oleifera Lectin. Process Biochem 44:504–508

[74] Luz L de, A., Silva, M.C.,Ferreira, R. 2013. Structural Characterization of Coagulant Moringa Oleifera Lectin and its Effect on Hemostatic Parameters. Int J Biol Macromol 58:31–36.

[75] Katayon, S., Noor, M.M., Asma. M. 2006. Effects of Storage Conditions of Moringa Oleifera Seeds on its Performance in Coagulation. Bioresour Technol 97:1455–1460

[76] Shebek, K., Schantz, A.B.,Sines, I. 2015. The Flocculating Cationic Polypetide from Moringa Oleifera Seeds Damages Bacterial Cell Membranes by Causing Membrane Fusion. Langmuir 31:4496–4502

All © 2023 are reserved by International Journal of Advanced Science and Engineering. This Journal is licensed under a Creative Commons Attribution-Non Commercial-ShareAlike 3.0 Unported License.